# The Integration of Western Hemisphere Grain Markets in the Eighteenth Century: Early Progress and Decline of Globalization

Rafael Dobado and David Guerrero

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## Resumen

En este trabajo se muestra que, si se acepta la definición de globalización como convergencia de los precios de mercancías de amplio consumo entre mercados distantes entre sí, el proceso comenzó y avanzó gradualmente in el siglo XVIII en vez de "explotar" después de 1820, como sostiene la versión canónica desarrollada en una serie de importantes trabajos de O'Rourke y Williamson (1999, 2002 y 2004). Usamos series históricas largas de precios de granos en varios mercados de Europa Occidental y América para determinar el alcance y la dinámica de la integración de mercados en el Hemisferio Occidental durante el siglo XVIII. Nuestra metodología es original, pues consiste en estudiar las desviaciones standard de las innovaciones en los modelos ARMA de las series de precios relativos entre pares de mercados. Un descenso general de la dispersión de precios se observa al comparar los inicios del siglo XVIII con las tres décadas que preceden a 1793. Ni Argentina ni México participan en esta tendencia general hacia una mayor integración de los mercados del Hemisferio Occidental. Entre 1793 y 1828 observamos un aumento sustancial de la dispersión entre mercados. Tras este primer retroceso, la globalización se relanzó a un ritmo antes desconocido gracias a la revolución de los transportes y otros factores.

**Palabras clave:** mercados de integración, globalización.

## Abstract

In this work it is shown evidence supporting the idea that, if globalization is defined as the convergence of commodity prices between distant markets, the process started and advanced gradually in the eighteenth century instead of suddenly appearing after 1820, as claimed by the canonical version developed in a series of important works by O'Rourke and Williamson (1999, 2002, 2004). We use long time-series of grain prices for several markets in Western Europe and the Americas to explore the extent and dynamics of market integration across the Western Hemisphere throughout the eighteenth century. An innovative methodology, consisting in studying the standard deviations of the innovations in the ARMA model of pairwise relative prices between markets, is used. A general decrease in price dispersion is observed when the early eighteenth century is compared with the three decades preceding 1793. Neither Argentina nor Mexico participated in this general trend towards closer market integration across the Western Hemisphere. From 1793 to 1828 we observe a substantial increase in dispersion between markets. After this first backlash, globalization resumed at an unprecedented pace since it was favored by the transport revolution and other factors.

**Key words:** market integration, globalization.

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# 1. Introduction

We agree with the opening statement of Federico's latest working paper: *"Market integration is one of the hottest topics in economic history."*[1] Indeed, an increasing number of scholars are devoted to deal with a topic that is intimately connected with globalization, one of the most common words in nowadays speech. We share Federico and Persson's (2007) opinion on the pioneer role that the research agenda developed by Jeffrey Williamson has played in the popularization of these two these two and interconnected themes.

In this work in progress we attempt at empirically testing the set of ideas that form what may be called the canonical version of globalization, as it has been established in three important works by O'Rourke and Williamson (1999, 2002, and 2004). To these authors, globalization means *"the integration of international commodity markets."*[2] They do not see evidence of *"significant pre-nineteenth century global price convergence"*.[3] The reason for that is the important role played in their narrative of globalization by the "transport revolution" of the nineteenth century resulting in the "amazing" decline in the cost of moving goods between markets: *"it was falling transport costs that provoked globalization."*[4] Summarizing the canonical version: *"Globalization became economically meaningful only with the dawn of the nineteenth century, and it came on in a rush."*[5] In later works, these authors show an increasing interest in developments that took place in the eighteenth century [O'Rourke and Williamson (2005); O'Rourke, Roses and Williamson (2007)]. However, the canonical version established by them is still very much influent, and not without good reason.

In his major contribution to this issue, Persson (1999), although recognizing that Southern and Northwestern Europe markets –or at least some of them- were integrated in 1730-1780, does not pay too much attention to the changes in the degree of integration over the eighteenth century. In their interesting article on European price convergence for several commodities during 1500-1880, Özmucur and Pamuk (2007) do not find evidence of market integration in the long-distance trade.[6] They claim that transportations costs did not decline and that, in general, political and institutional changes did not have any significant effect in international market integration. Bateman (2007) rejects any advance in integration of grain markets across Western Europe when the comparison is made between the levels of sixteenth and the late eighteenth centuries. Federico's extensive work on the convergence of grain and candle prices in Europe from 1750 to 1870 shows a picture that, although not identical, is coincident with that of O'Rourke and Williamson in at least two important respects: 1) dispersion of prices did not change during the second half of the eighteenth century; 2) falling maritime transportation costs significantly contributed to price convergence in the second quarter of the nineteenth century.

A novelty of our paper is of methodological character. Our approach to the analysis of market integration in history is, to the best of our knowledge, unprecedented. However, it has something in common with Llopis and Jerez (2001), Llopis and Sotoca (2005) and Treadway (2009). The period under scrutiny is 1703-1815, at least for all markets with continuous yearly price series for grains (wheat and corn).[7] These markets are Arevalo, Gdansk, Holland, London and Southern England –hereafter London-, Milan, Strasbourg and Vienna, in Europe, and Mexico and Pennsylvania, in America. Pennsylvania, whose series start in 1720, constitutes an exception. In some cases, it has been also possible to study a longer time-span: until 1827 (Holland, London, Milan, Pennsylvania, Strasbourg and Vienna) and until 1896 (Holland, London and Pennsylvania). We start by analyzing cointegration between original series of prices. We pro-

[1] Federico, 2008, p. 3.
[2] O'Rourke and Williamson, 2002, p. 25.
[3] O'Rourke and Williamson, 2002, p. 26.
[4] O'Rourke and Williamson, 1999, p. 35.
[5] O'Rourke and Williamson, 2004, p. 109.

[6] The graph showing the evolution of the coefficient of variation between several European markets for wheat shows unequivocal signs of decreasing dispersion in prices in most of the eighteenth century, which is interrupted during the three last decades.
[7] Only in a few cases, interpolations of one or two years have been necessary –see Appendix 1.

ceed by modeling the long-term price series available within an ARIMA framework. We also study several dozens series of pairwise relative prices (price ratios) between all these markets for wheat and corn –i. e. Holland/Arevalo, Mexico/Pennsylvania, etc.) through ARMA modeling. Especial attention is paid to the variance of the stochastic innovations in the estimated ARMA models –hereafter SDSI- for these pairwise relative prices (price ratios) over different time sub-samples.

The second novelty of this paper is empirical, albeit with some probable far-reaching implications. According to the main methodological hypothesis underlying this work –that changes in SDSI values may be interpreted in terms of price convergence- our findings are in themselves a reliable measure of the relatively large extent and fast dynamics of grain market integration throughout the Western Hemisphere over the period, central decades of the eighteenth century, in which the existence of globalization is denied by conventional wisdom. Therefore, we suggest a partial revision of mainstream views on the process of international integration of grain markets since substantial evidence in support of an early, gradual and non-monotonic convergence of grain prices throughout the Western Hemisphere –colonial Latin America not participating, though- in the eighteenth century is hereby offered. If international convergence of prices for commodities is taken as a necessary and sufficient condition of globalization, then globalization started before the nineteenth century, was caused by factors other than a transport revolution, experienced an early and temporary –albeit long-lasting- backlash by late eighteenth and early centuries and resumed afterwards, as the canonical version states, at higher pace. Thus, we suggest just a partial, conditional, revision of the canonical version as our research confirms some of its main points and departs from it only because of the inclusion of the eighteenth century in the picture.

Our empirical findings are consistent with Jacks (2004), as he shows a growing integration (albeit not without disintegrating phases –i. e. central decades of the seventeenth century) of grain markets within the North and Baltic seas since the Early Modern Era and an increasing synchronization, if not especially fast, of prices throughout the eighteenth century. They also coincide with those of Sharpe (2008). We offer statistical evidence that not only confirms the early integration of wheat markets between the US and Britain and its sensitivity to exogenous shocks –i. e. wars- that he demonstrates but also reveals a perceptible dynamics towards convergence with other European markets over the eighteenth century. Empirical results from our research are in line too with an increasing body of literature suggesting a grain market integration at the regional and national level in eighteenth century Europe that exceeds the rather low one traditionally supposed –i. e. Llopis and Jerez (2001) and Llopis and Sotoca (2005) for the Spanish case, in which institutional backwardness was reinforced by especially strong geographical obstacles. Probably, Bourbon Mexico was the only case in our sample for which a comparable combination of institutional and geographical impediments to domestic market integration might be assumed. In spite of it, Challu's work on late colonial Mexico posits that integration between distant corn markets increased after 1780. Özmucur and Pamuk (2007), albeit denying any continental trend towards closer market integration in 1500-1800, explicitly admit "*that parts of Europe were becoming more integrated within themselves and with other parts of the continent during the early modern era.*"[8] With respect to the eighteenth century, a favorable view on continental market integration may be drawn from Bateman (2007), as she recognizes the existence of "*an improvement in markets that took Europe to new heights of market development by the eighteenth century.*"[9] It is interesting to notice that the view of market integration through early modern Europe as a succession of integration and de-integration phases –i. e. Jacks (2004); Bateman (2007)- is compatible with our characterization of the globalization process from early eighteenth to late nineteenth centuries as a non-monotonic process that –with longer or shorter interruptions- persisted over the very long-run.

[8] Özmucur and Pamuk, 2007, p. 79. Moreover, the graph showing the evolution of the coefficient of variation between several European markets for wheat shows unequivocal signs of decreasing dispersion in prices in most of the eighteenth century, which is interrupted during the three last decades (Ibidem, p. 70).
[9] Bateman, 2007, p. 23.

Our empirical findings are not at odds with those of Rönnbäck (2009) either, since, after studying convergence of prices of 11 commodities other than grains (sugar, tobacco, cacao, etc.) from mid sixteenth to late eighteenth centuries, he concludes that the case for an early globalization, if defined by international convergence of prices, cannot be dismissed "*as easily as has often been doing so far.*"[10] They may also be reconciled with O'Rourke (2006). This author points out the enormous impact of the wars in 1793-1815 on international trade and suggests that *"there was already a potential for integration"* in the eighteenth century.[11] The long-term disintegration of international markets during the Revolutionary and Napoleonic wars, plus the effects of the US independence war on the Britain-North American trade, ought to be considered when examining convergence of prices in from the 1780's on. These shocks disturb the picture of market integration over the whole eighteenth century offered in some papers. Neither are our main results necessarily contradictory to Persson (1999). On the contrary, we find them complementary.

Our partial revision of the canonical version of globalization is influenced by the gradualist critique –initiated by Crafts (1985)- to the traditional narrative of the British industrial revolution and by the scholarship offering a more optimistic view on economic growth during the Early Modern Era [Persson (1988); De Vries (1999); Van Zanden 2002)]. In our view, globalization, interconnected with modern economic growth, started earlier and developed slower than is claimed in the canonical version.

We coincide with Bateman (2007) when she claims that: "*Markets are at the very center of economics.*"[12] Therefore, we believe that our conclusions might also be relevant to the "Great Divergence debate" [Frank (1998), Pomeranz (2000)]. The interesting contribution by Shiue and Keller (2007) posits that grain market integration in Western Europe and China was comparable by late eighteenth century. It is also their claim that by early nineteenth century a sudden increase in market integration accompanied industrialization in Western Europe instead of preceding it. We find something different and it has no minor implications for the debate. In the first half of the eighteenth century an early process of grain market integration on both continental (Europe) and intercontinental scales (North America and Europe) was already underway. Nothing similar was going on in China, which is consistent with some of the Pomeranz's arguments to explain the rise of the West. The process of market integration intensified in the second half of the century and was reversed by the Revolutionary and Napoleonic wars. In our view, widely exceeding the geographical extent that may be associated with the Chinese case in Shiue and Keller (2007), market integration at the European and Atlantic levels, then, preceded the most conspicuous manifestation of modern economic growth in the Western Hemisphere. Therefore our research may also contribute to the discussion about the fundamentals of modern economic growth [North (1981), Landes (1999), Acemoglu et al. (2004), Glaeser et al. (2004), Clark (2007)].

Besides this introduction, the paper contains three sections. The second section presents sources and a first, somewhat impressionistic, graphical exploration of data. In the third section briefly we briefly explain our theoretical and methodological approach to the analysis of market integration. This section also informs about the main empirical findings of our research. The economic implications of these findings are discussed in the fifth section. The paper finishes with some concluding remarks.

# 2. Sources and first exploration of data.

Sources of data are shown in Appendix 1[13]. In order to avoid the limitation on the time dimension of the analysis which results from controlling for monetary disturbances, we use a common unit of measure for all markets. Thus, prices are expressed in grams of silver per liter of grain. When needed, the conversion from local units to silver grams has been made –see Appendix 1. In contrast with Persson (1999), we

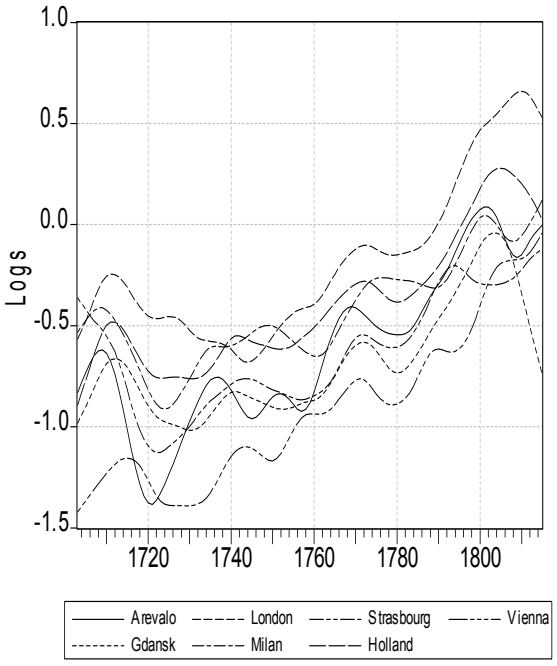
[10] Rönnbäck, 2009, p. 114.
[11] O'Rourke, 2006, p. 124.
[12] Bateman, 2007, p. 2.

[13] We feel obliged to acknowledge the enormous effort done by the authors from whose work we draw the data that comprises our sample.

use a methodology that is less demanding in terms of the frequency of observations since it permits to use annual data. On the contrary, it poses the requirement of working with long – practically- continuous time series.

Figure 1 shows the trends of wheat prices in seven European markets located in different parts of the continent and of which most of the literature, more or less explicitly, would possibly assume that they were not closely interconnected.

**Figure 1: Trends of wheat prices in Europe, 1703-1812. (Hodrick-Prescott filter).**




Source: Garner (1985), Llopis and Jerez (2001) and International Institute of Social History (http://www.iisg.nl/hpw/data.php).

Grain prices trends across most of Europe in the eighteenth and early nineteenth centuries share a basic similarity: they grew, especially from the 1740's and 1750's. By early nineteenth century the price trend in some markets had started to decrease while in others it was still growing. In general, all trends lay within the range of values established by London as the upper band and Vienna as the lower one. From mid eighteenth to early nineteenth centuries it is rather unusual to observe changes in the markets' relative positions along the scale of prices determined by the two extreme bands. A first impressionistic indication of the process of price convergence and divergence across European markets over the eighteenth and early centuries derives from Figure 1: dispersion between trends decreases from the relatively high levels in the 1700's to the 1730's to the absolute minimum of the late 1780's; from the 1790's on dispersion widens and reaches an absolute maximum in 1815. We have then preliminary evidence supporting the notion of market integration for wheat throughout Europe in the central decades of the eighteenth century and of its reversal during the period of the Revolutionary and Napoleonic wars.

The behavior of wheat in colonial Mexico is the only exception to the general rule within our sample, since it is the only stationary series. Whatever the reason of its singularity may be, we have excluded from this study because, among other reasons, it was far from being the main staple in colonial Mexico. Living apart the colonial Mexico's wheat series, the trends of grain prices in the two American markets behave in a way that very much resembles that one already seen in the case of Europe: in contrast with the first half of the eighteenth century, the second half is characterized by a positive rate of growth.

# 3. Theoretical and methodological approach

This section draws from previous work by several scholars: especially, although not only, Llopis and Jerez (2001), Llopis and Sotoca (2005), Persson (1999, 2008), Federico (2008) and Treadway (2009).

In this section we present an innovative methodology, consisting in studying the standard deviations of the stochastic innovation in the univariate ARMA model of pairwise relative prices (price ratios) between markets, enables us to find solid evidence of integration during the whole eighteenth century (Subsection 3.3). Studying the standard deviations of the stochastic innovation is possible and may be interpreted in terms of market integration because nominal prices in our sample are cointegrated CI(1,1) to each other and hence pairwise relative prices are

stochastic stationary, i.e. with cointegration coefficients (1,-1). Previously, in the subsections 3.1 and 3.2, we present the Univariate Analyses for the nominal price series and for the pairwise relative price (price ratios) series.

### 3.1 ANALYSES FOR THE NOMINAL PRICE SERIES.

Data analysis begins with single-variable analyses for each nominal grain price (in logs) included in the study ($P_t$). Let $B$ stand for the lag or backshift operator such that, for any time series $P_t$, $BP_t \equiv P_{t-1}$, and let be $\nabla$ the difference operator such that $\nabla \equiv 1 - B$ and

$\nabla P_t \equiv P_t - P_{t-1}$.

Nominal price series in our sample need to be transformed into neperian logarithms to avoid heteroskedasticity, non-normality and non-linearity, so that $P_t$ can be plausibly assumed to follow homoskedastic, normal linear stochastic processes.

Findings are very similar for all nominal grains prices (in logs) studied: all the $P_t$ series are I(1) and their first difference, $\nabla P_t$, has (i) zero mean, (ii) AR(2) structure with two conjugate imaginary roots, giving rise to damped oscillations with a period of 5-11 years and damping factor around 0.5, (iii) and MA(1) structure. In some cases, there are a small number of influential impulse interventions[14] in the series level ($P_t$). Therefore, generic univariate model for $P_t$ can be written like bellow:

$P_t = \xi_t + N_t, \quad \phi(B)\nabla N_t = \theta(B)a_t$ iid $N(0,\sigma_a^2)$

where $\phi(B) = (1 - \phi_1 B - \phi_2 B^2)$ and $\theta(B) = (1 - \theta B)w$

with $\phi_2 + \phi_1 < 1$, $\phi_2 - \phi_1 < 1$, $|\phi_1| < 1$, $|\theta| < 1$ and $\phi^2_1 + 4\phi_2 < 0$

and where $\xi_t$ represents a sum of intervention terms, each of the form $\omega_0 \xi_t^{I,t^*}$ for a parameter

$\omega_0$ and

$$\xi_t^{I,t^*} \equiv \begin{cases} 1.0 & t = t^* \\ 0.0 & t \neq t^*. \end{cases}$$

Results are summarized in Table 1.[15] The residuals for each estimated model seem to be well centered at zero mean and approximately homoskedastic. No more than seven residuals of the 113 available (96 in PW and PC cases), are above two residual standard deviations in absolute terms. This number is not excessive for the normal distribution, and none of the largest residuals is very extreme. On the other hand, graphs of residual acf/pacf reveal no further structure. Finally, there is nothing in the estimated models or the diagnostic tools that suggest overdifferencing. Thus the models seem to be well specified. By the Generalized Likelihood Ratio Test of Davis, Chen and Dunsmuir (1995), DCD, we can reject the null hypothesis of MA(1) noninvertibility, since the likelihood ratio is much higher than the cut-off values of 4.41, 1.94 and 1.00, which are those for confidence levels of 99, 95 and 90% respectively (See Table 1). Therefore, I(1) is confirmed in all cases.

### 3.2 ANALYSES FOR THE PAIRWISE RELATIVE PRICES (PRICE RATIOS) AND COINTEGRATION CI(1,1)

The logarithm is applied to all relative prices as a logical consequence of applying it to nominal prices. Observe that $R_{it} = \ln(P_{it} / P_{jt}) = \ln P_{it} - \ln P_{jt}$ for all $i \neq j$.

Note that, if $P_{it} / P_{jt} = 1$ then $\ln(P_{it} / P_{jt}) = 0$. This deterministic notion of a constant in time relative prices has a long history of being defined as "the law of one price" (LOP).

In order to test if LOP is fulfilled for grain historical series, we study the series of the relative prices (price ratios) following the framework exposed in detail in Treadway (2009). That is, all pairs of nominal prices satisfy a CI(1, 1) relationship with cointegration coefficients (1,-1), when the log of the corresponding relative price is stationary and the nominal prices are I(1). See Engle and Granger (1987) for the definition of

[14] A complete numerical listing of all intervention (dates and estimated values) is available from the authors on request. In the most European series we define interventions terms for the years: 1795, 1799-1801. In the case of Penn data: 1739-1742, 1778-1780, 1782. In all cases, the specifications for the interventions are empirically founded and have an historic explanation.

[15] Additional graphic and statistical information, including complete specification and diagnostic instruments, are available under request.

CI(1,1). Quoting Treadway (2009), "*the relevant generalization of the deterministic notion of a constant in time is to the statistical concept of a stochastic process stationary in mean, that is, the expected value exists and does not vary with time. There may be transitory variations, but a long run average exists and is constant in time.*"[16] Therefore, we only need of the univariate analysis of relative prices to conclude about cointegration relationships between grain prices.

Next we summarize the results of the univariate analysis of pairwise log-relative prices for London (reference market in this paper), in different subsamples: 1703-1815, 1703-1792, 1703-1757, and 1758-1792. In theory, if the nine possible log-prices ratios pairwise with London are stationary, that is I(0), any of the other log-price ratios, among the rest of the markets, are also stationary. We use this theoretical result to conclude. On the other hand, although it is no necessary to conclude on the market integration, we also present the built model for the relative wheat price for Holland/Pennsylvania in the sample 1867-1896, because it is used like a reference measure for the standard deviation of the innovation in the model for other relative prices.

In all of these cases a CI(1,1) relationship is found. Furthermore, the relative prices ($R_{ij}$) are I(0), has mean and AR(1) structure[17][18]. The generic univariate model for an $R_{ij}$ can thus be written:

$$R_t = \mu + N_t, \quad \phi(B)N_t = a_t \text{ iid } N(0,\sigma_a^2)$$

where $\phi(B) = (1- \phi_1 B)$ with $|\phi_1| < 1$.

Results are summarized in Tables 2 and 3.[19] The residuals for each estimated model seem to be well centered at zero mean and approximately homoskedastic, and none of the largest residuals is very extreme. Graphs of residual acf/pacf reveal no further structure. Finally, there is nothing in the estimated model or the diagnostic tools to suggest non-stationary, so the model seems to be well specified. By the Likelihood Ratio Test of Shin and Fuller (1998), SF, we can reject the null hypothesis of AR(1) non-stationary, since the likelihood ratio is much taller than the cut-off values for confidence levels of 95 and 90% respectively (See Tables 2 and 3). Therefore, a CI(1,1) relationship is found in all cases, no sensitive to the sample size.

### 3.3 STUDY OF THE VARIANCE OF THE INNOVATIONS (RESIDUALS) OF RELATIVE PRICES MODELS

Once that results under the CI(1,1) relationship have been established, one can consider the economic interpretation of the estimated values of mean (log) relative prices, when these are stationary. Or the estimated residual standard deviation (SDSI) may vary; when it falls, that suggests more rapid short term adjustment in the market.

There are several reasons why it is better to study SDSI of the price ratios than the correlation coefficients to analyze the integration of markets. Firstly, the variance of a non-stationary series is not defined. Secondly, the autocorrelation structures of the series that distort the measure of each price series variance have to be previously detracted in order to properly study the relation between series. On the contrary, these problems disappear when price ratios are stationary. In this case it is possible to study whether the innovation variance is homogeneous or heterogeneous, whether this variance increases or decreases, or even whether there is evidence supporting the existence of a higher variance in a certain period. Within this theoretical and methodological framework, we considerer that a significant reduction in the innovation variance is an unequivocal evidence in favour of an increasing market integration.

It may be observed that our measure of market integration yields plausible results. Differences across time and space make sense: SDSI values – column at the extreme left of Table 2- are higher for A/L and MC/L than for PC/L, H/L and PW/L; they are also substantially lower in 1867-1896 than in 1703-1815 or in 1720-1815. However our main interest consists in detecting changes throughout the eighteenth century, in particular before the period of Revolutionary and Napoleonic wars. That is why we show Table 3, in which different time subsamples are examined.

[16] Treadway, 2009, p. 10.
[17] Intervention terms are compatible and are specified in the same form that the nominal prices models.
[18] In some cases AR(2) structure with two conjugate imaginary roots are found.
[19] Again, all additional information that may be required is available under request to the authors.

ARMA models have been built for each of the dozens of series of pairwise relative prices (price ratios) in the sample, being the time span 1703-1815, except for Pennsylvania which is 1720-1815.[20] From these models we estimate the SDSI values for the time subsamples 1703-1737, 1731-1765 and 1758-1792 for all series. We use the same specification as in the model for the whole time span of each series. As the available data permit it in three series of pairwise relative prices (price ratios) for wheat (London/Holland, London/ Pennsylvania and Holland/ Pennsylvania), new ARMA models are built for 1867-1896. Thus, we are able to compare the late nineteenth with the eighteenth centuries. In fact, we use the estimated SDSI values in these three markets as a measure of the maximum possible integration before the twentieth century. Therefore, indirectly, our approach yields an ad hoc metric of the process of market integration through the eighteenth and nineteenth centuries. Moreover, this additional modelling for 1867-1896 responds to the evidence-based presumption that a structural break in the series due to changes in transaction costs may be dated sometime in 1815-1866.

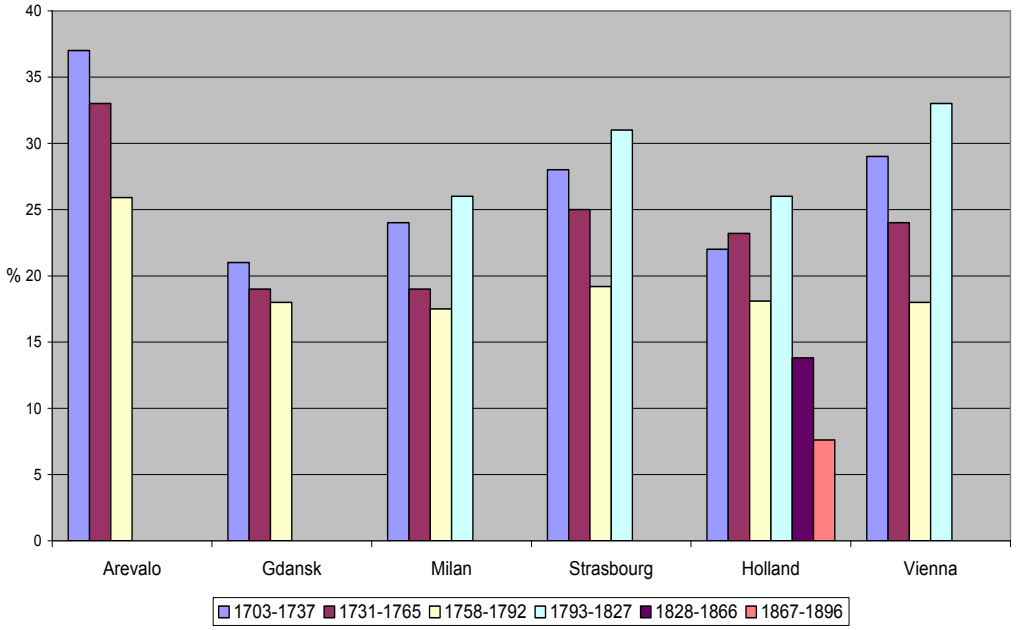
Estimating the SDSI values for 1793-1827 is done by using the same models as for 1703-1815. The underlying assumption is that no big changes are expected during that peculiar period of almost constant disruption of the international trade which started in 1793. The consistency between all estimated –and clearly growing standard deviations for 1792-1827 is reassuring. Less convincing is that the model for 1703-1815 is used to estimate the deviation for 1818-1866. We will improve this estimation In any case, any possible bias in our measure of integration for this period does not affect too much to the main argument defended in this paper. Besides, it is our intuition that results from a specifically modelling the series for that period ought not to be very different.

In Figure 2 the SDSI values of London with respect to other European markets for wheat are shown. Figures 3 and 4 depict similar information for Pennsylvania and Milan, respectively,

Other European markets experienced similar decreases in SDSI values between 1703-1737 and 1758-1792 and increases in 1793-1827.

## Figure 2

**Standard deviation of the innovations in the ARMA model: London, 1703-1896.**

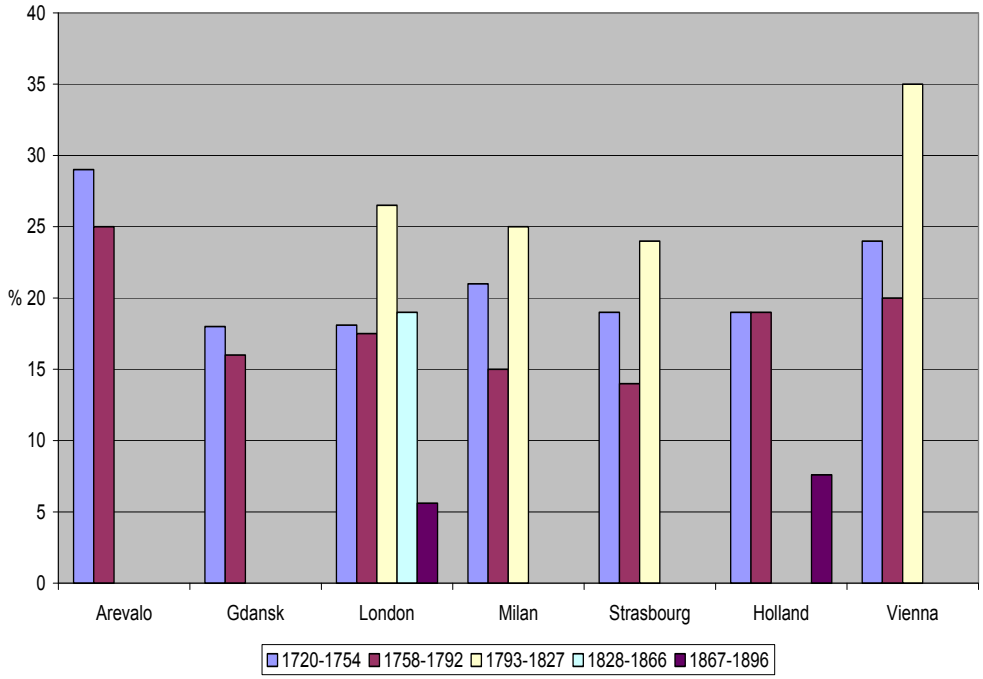



Source: See Appendix 1.

[20] Not shown here, they available under request to the authors.

## Figure 3

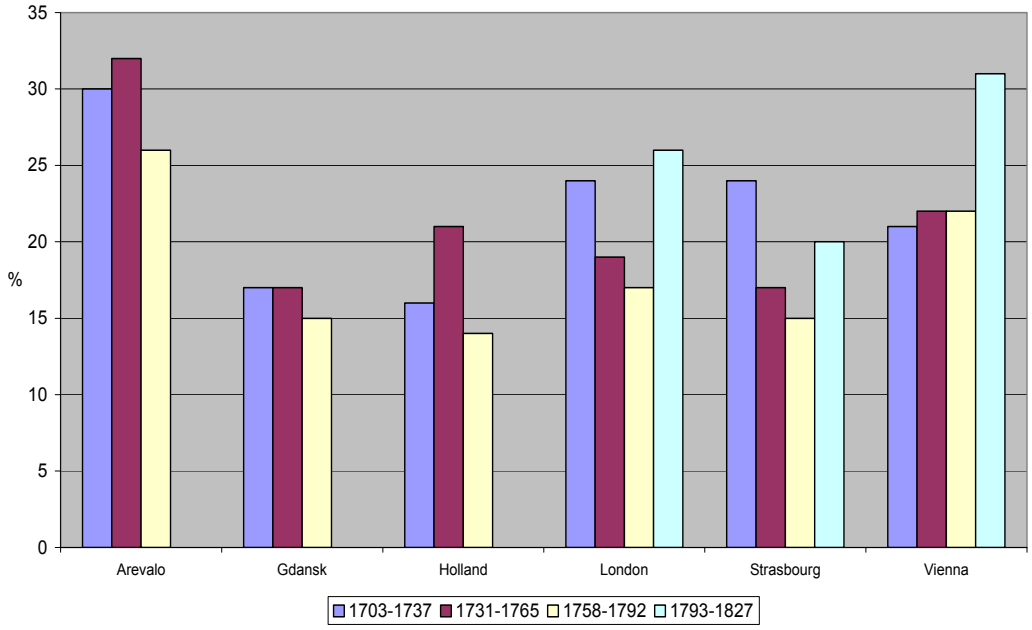
**Standard deviation of the innovations in the ARMA model: Pennsylvania, 1720-1901.**




Source: See Appendix 1.

## Figure 4

**Satandard deviation in the ARMA model: Milan, 1703-1827.**




Source: See Appendix 1

# 4. Economic implications of main empirical findings.

This section briefly discusses the main economic implications that may be derived from our empirical analysis.

Our main concern being market integration, we do not even mention some interesting findings that result from the ARMA modeling of the grain prices series. We have found an almost general cointegration between all series in the sample. In other words, the existence of a common non stationary factor for all series can not be rejected. In other words, almost all price series are cointegrated. That is probably interesting. However, the economic interpretation of this empirical finding is not self-evident –see Federico (2008) for, to the best of our knowledge, the most comprehensive discussion of the methodological issues regarding market integration analysis. We share with him the idea that cointegration is not a sufficient condition of market integration in terms of LOP. The fact that the series of corn prices in Mexico is cointegrated with that of wheat prices in Arevalo –and with others- is interesting in this regard, as no possible commercial interaction between these two markets can be imagined. We have also found that the SDSI values of nominal prices and of the pairwise relative prices (price ratios) present empirical regularities (levels and changes across time and space) that maybe interpreted in terms of market integration. Have can we explain simultaneously cointegration and dispersion?

We may think of two explaining hypothesis. We term them the "Malthusian" and the "integrating markets" hypothesis. The "Malthusian" hypothesis consists in assuming that all markets experienced similar changes in supply and demand conditions. Thus, similar changes in main factors determining grain prices over the long run (population growth, income and wealth distribution patterns, agricultural technology, climate oscillations, etc.) resulted in similar trends in of all series of nominal prices. In this paper we do not pay attention to factors behind cointegration between nominal prices. As to the explanation of the changes in the dispersion in the series of relative prices, the "integrating markets" hypothesis seems more promising. In fact, this is the hypothesis that we are testing.

Our test of the "integrating market" shows, taking the degree of integration in a few relevant markets (PW-L, PW/H and H/L) in 1867-1896 –see Table 2- by the standard of comparison -as measured by their SDSl values- an interesting and new picture of the process of commodity market integration in the Western Hemisphere over the eighteenth and nineteenth centuries emerges. Main features of this picture are the following:

1) By early eighteenth century a wide geography of markets for wheat in the Western Hemisphere (H/G, PW/G, M/G, L/PW, M/H, S/PW and PW/H) seems to be already significantly integrated. They all show values of their SDSI in 1703-1737 below twice that of the late nineteenth century. Given high transport costs, mercantilist commercial policies and other factor influencing markets integration (piracy, international conflicts, privileged companies, etc.), our results for early eighteenth might be considered 1737 surprising high, although limited to only a few markets in our sample. Other markets, Arevalo and Mexico in particular, were much less integrated, if at all.

2) In the three and a half decades preceding the start of the Revolutionary and Napoleonic wars market integration substantially increased in the majority wheat markets. Sixteen pairs of markets for wheat –almost all those formed by Gdansk, Holland, London, Milan, Pennsylvania and Strasbourg- out of twenty-eight reduce the SDSI values below twenty percent. Thus, by mid eighteenth century, the geography of the integration market integration expanded from the Atlantic, North and Baltic seas to include other parts of Europe. Only in five pairs of markets for wheat (five pairs markets out of twenty-eight) the SDSI values are higher in 1758-1792 than in 1703-1738. Arevalo, which –because of its isolation from the sea or from other water ways and of the comparative institutional backwardness of Spain- may be taken as an extreme case relative to the rest of markets for wheat, also participates in this general trend towards closer integration, albeit it still maintains high SDSI values by any standard.

As an example of the "early progress" of globalization in the Western Hemisphere, between 1768 and 1806, Cadiz, in a rather "close economy", when compared to those of Britain or Holland, as that of Spain, imported significant quantities of wheat and flour from Northern Europe, Italy and Western Mediterranean, Eastern Mediterranean and Black Sea, North America and Atlantic Africa-Berberia (Martínez Ruíz, 2005). Curiously enough, in Spain, geographical and other obstacles to a closer market integration between central regions (net producers of wheat) and coastal regions (net consumers of wheat) favored the connection of the later with other, more distant, national or international markets[21].

Developments in Russia, a relatively "late comer" to the expansion of world trade in early modern times, are also interesting. Referring the works of Kahan, Findlay and O'Rourke (2007) show that Russian exports of grains experienced a several-fold increase, in either relative or absolute terms, from the beginning to the end of the eighteenth century.[22] Findlay and O'Rourke (2007) also inform about grains export from British New world colonies in 1768-1772. Significant quantities of grains were exported from the Middle Colonies to Europe other than Great Britain and Ireland. In fact, grain exports to the Continent widely exceeded those to the two islands, being similar to those to the West Indies[23].

The interesting finding –see Table 3 in Appendix 2- that all London's pair markets for wheat tended to a SDSI value of 18%, which we interpret as a reliable measure of the maximum possible convergence of prices in eighteenth century, is confirmed for other markets as well. In some pair of markets for wheat (most clearly in M/G, H/G, PW/M, S/M, H/M and PW/S) this assumed maximum of price convergence was even over passed.

Curiously enough, some signs of β-convergence within our sample appear when we plot the percent reduction in average SDSI values of each market for wheat with the rest between 1703-737 and 1759-1792 against the SDSI in 1703-1737. If these signs were confirmed for a wider sample of markets, the hypothesis of a faster integration during the eighteenth century in those initially less globalized markets for wheat might be worth exploring.

Corn markets in America (Mexico and Pennsylvania) did not follow a trend towards closer market integration. In the Mexican case, as it might be expected, there is no substantial evidence of integration with other markets –see Figure 5.

Dispersion not only remains very high comparatively to the rest of western markets (wheat or corn, Europe or Pennsylvania) but it does not show any significant decrease between the two time subsamples. Especially telling is the low – or inexistent at all- integration between the two American corn markets (Mexico and Pennsylvania) in spite of such a big difference in prices as to open the possibility of trade. Probably, imperial regulations on commerce prevented this potential from becoming reality.

That colonial Latin America remained, as opposed to the colonial US, outside this early process of grain market integration is clearly showed by another instance that we have not been able to fully explore yet: Buenos Aires, capital since 1776 of the Viceroyalty of Río de la Plata and later on of Argentina, one the main participants in the canonical period of globalization. The comparison between the pairwise relative prices (price ratios) for wheat between London (L-SE) and Buenos Aires (BA) and L-SE and Pennsylvania (P) in most of the eighteenth century is very expressive. Whereas the price ratio L-SE/P shows a clear trend towards 1, which is consistent with the idea of integration between the two markets, the price ratio L-SE/BA moves around 1 until mid century and then continuously grows, which indicates the absence of any trade between the two markets –see Figure 6.

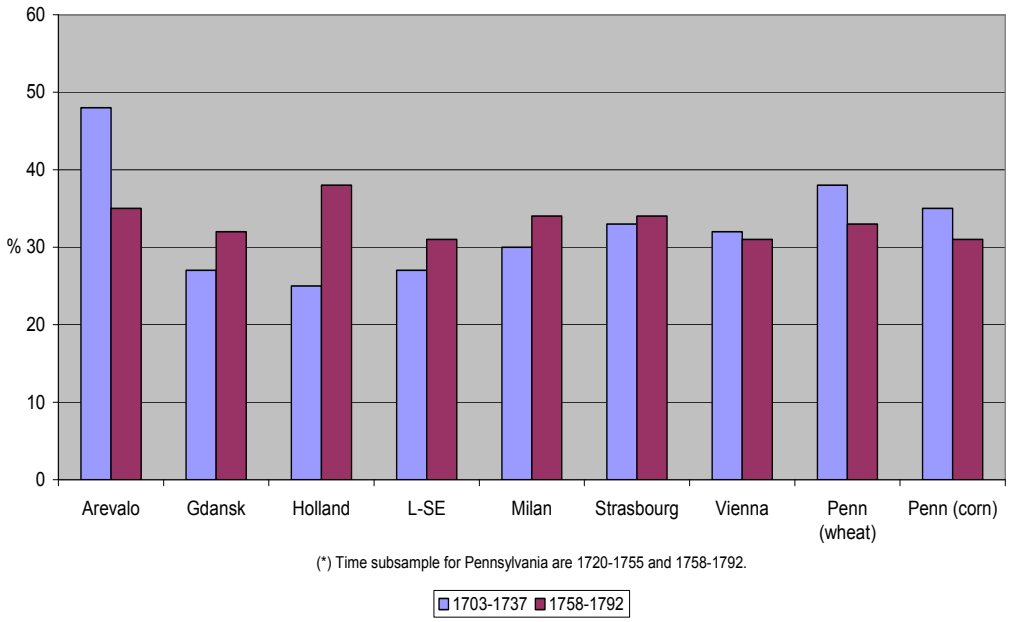
[21] In the words of the major of Alicante in 1769, when the areas surrounding the town were unable to produce large amounts of wheat: "*there is no remedy but the sea, with the wheat from Andalucia and Aragon, …, or from Abroad, …, since that of Castille and La Mancha, even when there is, they do not bring it because of the expensiveness of the* (inland) *freights"*. Quoted in Madrazo (1984), p. 737. Other similar instances may be found in Anes (1974).

[22] Findlay and O'Rourke (2007), p. 302.

[23] Grain exports from New England to "Other Europe" also clearly outnumbered those arriving to Great Britain and Ireland, albeit both influxes were of minor importance. Findlay and O'Rourke (2007), pp. 234-235.

## Figure 5

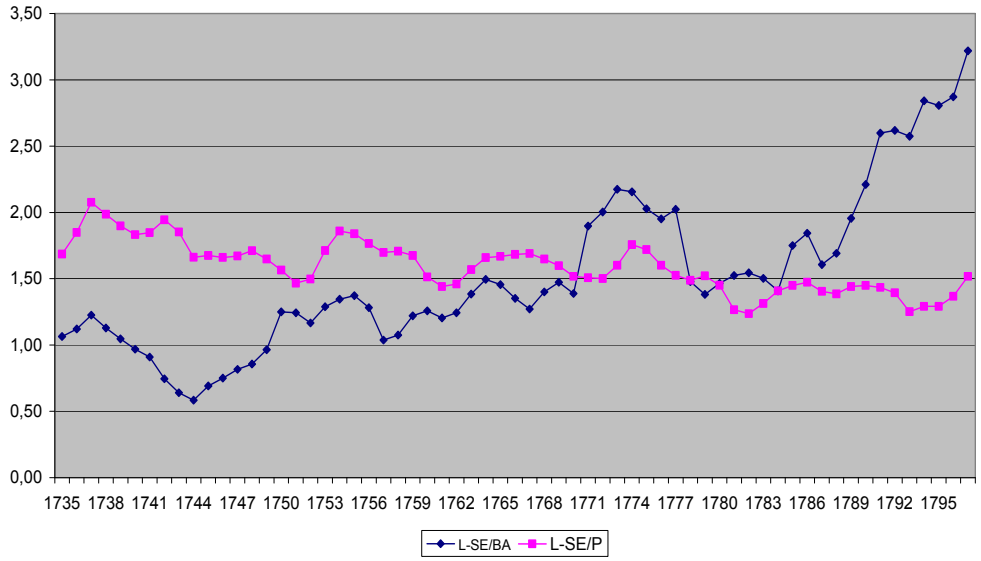
**Standard variation of the innovations in the ARMA model: Mexico.**




Source: See Appendix 1.

## Figure 6

**Pairwise relative prices (price ratios), 1735-1797. (Seven-year moving averages)**




Source: GPIHG web page **(http://gpih.ucdavis.edu/)**.

As to the Pennsylvania market for corn, the picture is somewhat more complicated. Firstly, the variance of the innovations in the ARMA model of the pairwise relative prices (price ratios) with the rest of markets for wheat and corn in Europe or America is significantly lower than in Mexico. Secondly, in some cases –Pennsylvania (wheat), Holland, London, Milan and Gdansk for 1720-1754 and Penn (wheat) and London for 1758-1792- the variance is comparatively low (SDSI values below 20%). Our interpretation is that the market for corn in Pennsylvania somehow reflected what was going on in the market for wheat, which in turns shows clear signs of integration, be it increasing or not, with other markets for wheat in Europe. In a peculiar way, though, since, in contrast to pairwise prices (price ratios) of Pennsylvania relative to the rest of wheat markets, no general reduction in dispersion is observed during 1758-1792. A role in human diet different to that of wheat in Western countries may also help to explain its peculiarities.

3) Consistently with O'Rourke, all ten markets for wheat in our sample for 1793-1827 unequivocally experienced a substantial decreased in integration with respect not only to 1757-1792 but also –M/S being the only exception- to 1703-1737. Our findings confirm Persson's intuition on the behavior of price volatility in Europe during the French Revolution and the Napoleonic wars[24]. They are also consistent with the *"dramatic change"* in European grain price dispersion in the 1790's and its persistence at comparatively high or very high levels until the return to pre 1790's levels in the 1830's that is observed by Federico (2008).

4) Since sometime rather late in the first half of the nineteenth century, as canonical version of globalization, market integration and, for that matter, globalization for that matter, resumed at an unprecedented pace favored by the transport revolution and changes in policy.

If we accept O'Rourke and Williamson's definition of globalization as price convergence, especially in the prices of commodities, between distant markets, we are forced, then, to conclude that globalization is genuinely perceptible, and that declined, several decades prior the time that it is postulated by the canonical version. From this perspective, our work may be considered a partial revision of the canonical version of globalization as it emphasizes an earlier origin, a more gradual start, a longer duration and a non-monotonic evolution over almost two centuries.

In other words, the undeniable globalization boom in the mid nineteenth century was preceded by a "mini-boom" in the second half of the eighteenth century. From a very long-run perspective, our picture is one of globalization as a less explosive phenomenon as it had a first phase in the 1750's, 1760's, 1770's and 1780's that converts it into a more gradual process than usually recognized in the specialized literature. Besides, the post-1914 globalization backlash might turn to be not strictly unique as it would have had a historical precedent in the enormous disruption of international trade caused by Revolutionary and Napoleonic wars that O'Rourke (2006) demonstrates.

Another way to put is that globalization did not strictly came in a rush but it probably appeared gradually as a further step in a sort of expanding waves that goes, not without general or particular interruptions, from the regional to the international levels all along the early modern era.

Our research has not gone deep into the causes of the earlier than usually claimed progress of globalization whose existence we are defending. Very probably, a further exploration of Persson (1999) insights into the effects, probably underestimated so far in the literature, of more pro-market policies adopted during the "first phase" by the enlightened elites (liberalization of internal trade, external trade barriers becoming more transparent and predictable and less protectionist tariffs)[25], along with some reduction in transport costs which may have been somewhat overlooked as well –see, for instance, Bogart (2004)- and in other transaction costs would suffice to offer a satisfactory explanation[26]. Transaction costs that limit the effectiveness of the LOP do not necessarily need a revolution in transport to substantially decrease. They may be reduced

[24] Persson, 1999, p. 113.

[25] Persson, 1999, p. 137.

[26] The importance of cabotage traffic might have been underestimated as well. Buti, consulted at http://rives.revues.org/document164.html, offers significant examples of wheat cabotage trade between the Paris Basin and Italy and France and Naples through Arles.

through small cumulative improvements along the transport chain –from short-distance terrestrial trade to long-distance maritime trade-, less restrictive tariffs, weaker internal institutional barriers to grain commercialization, safer sailing, etc. In this respect, Rönnbäck (2009), drawing from several authors, suggests that decreasing monopoly rents and handling and wastage costs reductions could be a source of international market integration for commodities before the nineteenth century.

# 5. Final remarks.

We tried to offer a more detailed version of the process of commodity market integration within the Western Hemisphere that is more gradualist than the canonical one and that is based in our economic interpretation of some interesting findings obtained through a simple technique.

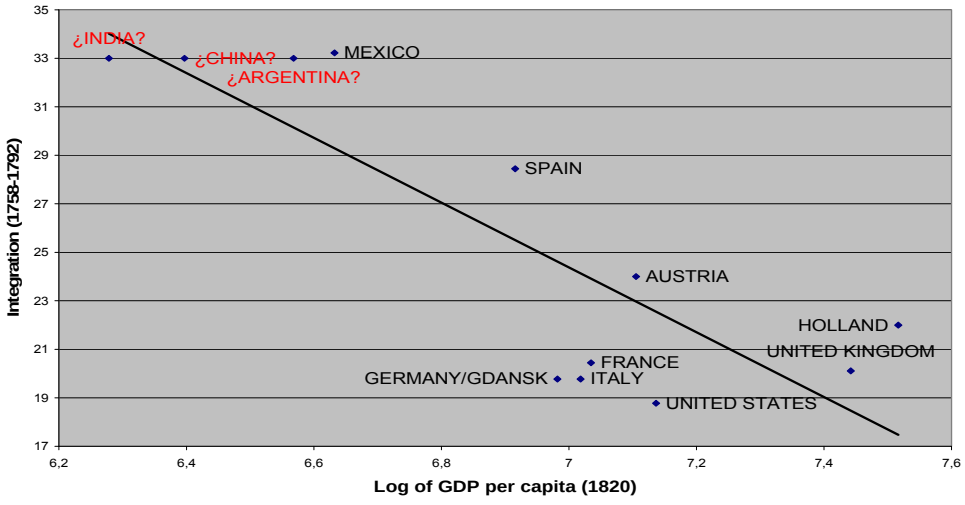
Future extensions of this work include:

1) Further exploitations of the preliminary results from the time series analysis performed so far. On the one hand, at the methodological level, examining closer the issue by means of expanding the sample in terms of grain markets and of the period scrutinized and additionally performing more formal test of hypothesis. On the other hand, at the empirical level, a deeper analysis of cointegration equations and ARMA models aiming at making possible an economic interpretation of the causes and consequences of the common trends and cycles observed in the series and of the possible structural changes between time sub-samples in those models. It seems also worth exploring whether there is any connection between these cycles and changes in the SDSI values.

2) Deeper examination of our findings' potential regarding the assessment of the causality between market integration and modern economic growth and the "Great Divergence debate" in line with Shiue and Keller (2007). Consciously, we present in Figure 7 a first, very speculative, piece of empirical evidence in favor of the hypothesis that a certain degree of intercontinental commodity market integration was already present when modern economic started in the Western Hemisphere.

Data on GDP per capita are taken from Maddison's web page. The main -too risky?- assumption underlying Figure is that levels of intercontinental commodity market integration in the second half of the eighteenth century, as measured by the average SDSI with the rest of markets in our sample for 1758-1792, were in Argentina, China and Argentina roughly equal to that of colonial Mexico, which is not very implausible. Additional assumptions are that the representative GDP per capita for Gdansk and Argentina are the German and the Latin American ones, respectively. If the mentioned assumptions were realistic enough, the –impressionist- picture would be that intercontinental commodity market integration was positively correlated with development before industrialization.

**Figure 7 : Market integration and economic development circa 1800.**




Source: GDPs per capita taken from Maddison web page (http://www.ggdc.net/maddison/).

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# Appendix 1

Sources of data and methods of conversion from local units into grams of silver per liter are:

**Arévalo**, **1703-1815**: Wheat prices in reales de vellón per fanega from Llopis and Jerez (2005). Conversions of Spanish units into grams of silver per liter: 1 fanega = 55,5 liters; reales de vellón converted into grams of silver at rates of exchange from Hamilton (1988). From 1801 onwards, the exchange rate vellón/silver in 1801-1815 is assumed to be that of 1800.

**Gdansk**, **1703-1815**: Wheat prices in grams of silver per liter from series elaborated by Robert C. Allen -see http://www.nuff.ox.ac.uk/users/allen/studer/gdansk.xls.

**London and Sothern England**, **1703-1896**: Wheat prices in grams of silver per liter from series elaborated by Robert C. Allen -see http://www.nuff.ox.ac.uk/users/allen/studer/london.xls.

**Milan**, **1703-1827**: Wheat prices in grams of silver per liter from series elaborated by Robert C. Allen -see http://www.nuff.ox.ac.uk/users/allen/studer/Northern%20Italy.xls. Missing data for years 1805-1806 have been calculated by simple linear interpolation.

**Mexico**, **1703-1815**: Corn prices in silver reales per fanega from Garner (1985). Conversion of colonial units into grams of silver per liter: for the sake of consistency with Pennsylvania corn prices (expressed in grams of silver per kilo), a kilo/liter ratio of 0.721 [GPIHG (http://gpih.ucdavis.edu/files/Weight_vs_volume.xls)] has been used; silver content of the real from Burzio (1956-1958).

**Pennsylvania**, **1720-1896**: Wheat prices in grams of silver per kilo from the GPIHG (http://gpih.ucdavis.edu/files/Penn_spliced_1720-1896.xls). The kilo/liter ratio used for wheat is 0.772. Corn prices in grams of silver per kilo from the Global Price and Income History Group (http://gpih.ucdavis.edu/files/Penn_spliced_1720-1896.xls). Kilos of corn converted into liters at a ratio of 0.721 [GPIHG (http://gpih.ucdavis.edu/files/Weight_vs_volume.xls)].

**Strasbourg**, **1703-1827**: Wheat prices in grams of silver per liter from series elaborated by Robert C. Allen -see http://www.nuff.ox.ac.uk/users/Allen/studer/strasbourg.xls. Missing data for years 1794-1795 have been calculated by simple linear interpolation.

**Vienna**, **1703-1827**: Wheat prices in grams of silver per liter from series elaborated by Robert C. Allen –see http://www.nuff.ox.ac.uk/users/allen/studer/vienna.xls.

**Upper Bajío**, **1703-1790**: Wheat prices in silver reales per carga from Garner (1993). Conversion of colonial units in grams of silver per liter: 1 carga equals 149.578 kilos [Florescano, (1986)]; the kilo/liter ratio used is 0.772 [Global Price and Income History Group (http://gpih.ucdavis.edu/files/Weight_vs_volume.xls)] as for the series of Pennsylvania wheat.

**Holland**, **1703-1896**: Wheat prices in grams of silver per liter from series elaborated by Robert C. Allen –see http://www.nuff.ox.ac.uk/users/allen/studer/amsterdam.xls. Missing data for years 1802-1803 have been calculated by simple linear interpolation.

## Appendix 2

Table 1: Estimated Univariate Models for First Log Differences of Yearly Price Data: ARMA estruture

| Samp. | Variable (Mnemonic) | AR(2) $\phi(B) = (1-\phi_1 B-\phi_2 B^2)$ | | Properties AR(2) Factor | | MA(1) $\theta(B) = (1-\theta B)$ | DCD(1) $H_0:\theta=1$ (90%, 95%) | $\hat{\sigma_a}$ (%) |
|---|---|---|---|---|---|---|---|---|
| | | $\hat{\phi}_1$ (s.e) | $\hat{\phi}_2$ (s.e) | Period (years) (s.e) | Damp. Factor (s.e) | $\hat{\theta}$ (s.e) | (1.0, 1.9) | |
| **Table 1.A Grains Europe in XVIII Century (Wheat)** | | | | | | | | |
| 1703-1815 | London-Southern England (L) | .60 (.11) | -.21 (.10) | 7.4 (2.1) | .45 (.11) | .80 (.07) | 11.9 | 20.0 |
| | Arevalo (A) | .75 (.10) | -.22 (.10) | 9.8 (4.2) | .47 (.10) | .90 (.05) | 8.3 | 31.4 |
| | Holland (H) | .62 (.15) | -.28 (.11) | 6.6 (1.6) | .53 (.10) | .73 (.15) | 12.1 | 15.2 |
| | Milan (M) | .66 (14) | -.59 (.08) | 5.6 (.5) | .77 (.05) | .32 (.18) | 26.1 | 12.2 |
| | Strasbourg (S) | .50 (.20) | -.41 (.10) | 5.4 (.8) | .64 (.08) | .50 (.22) | 14.1 | 16.2 |
| | Gdansk (G) | .94 (.10) | -.27 (.09) | 13.6 (9.3) | .52 (.09) | .90 (.06) | 5.8 | 13.3 |
| | Vienna (V) | .69 (.11) | -.17 (.10) | 10.4 (6.7) | .42 (.12) | .86 (.06) | 12.0 | 21.6 |
| **Table 1.B Grains America in XVIII Century** | | | | | | | | |
| 1720-1815 | Pennsylvania/ Wheat (PW) | .58 (.14) | -.38 (.10) | 5.8 (0.5) | .62 (.08) | .67 (.13) | 20.1 | 16.9 |
| | Pennsylvania/ Corn (PC) | .53 (.14) | -.27 (.11) | 6.1 (1.2) | .52 (.11) | .76 (.11) | 7.4 | 16.7 |
| 1703-1815 | Mexico/ Corn (MC) | .62 (.12) | -.14 (.11) | 10.3 (9.0) | .38 (.14) | .86 (.07) | 7.0 | 29.8 |
| **Table 1.C Grains Europe and America in XIX Century (Wheat)** | | | | | | | | |
| 1867-1896 | L | .17 (.26) | -.51 (.19) | 4.3 (0.6) | .71 (.13) | .37 (.28) | 5.9 | 9.0 |
| | H | .44 (.39) | -.30 (.20) | 5.4 (2.1) | .54 (.18) | .50 (.39) | 1.9 | 9.9 |
| | PW | .14 (.24) | -.55 (.17) | 3.8 (0.5) | .74 (.11) | .28 (.25) | 8.3 | 9.1 |

Notes:
(1) By the Generalized Likelihood Ratio Test of Davis, Chen and Dunsmuir (1995) test (DCD) we can reject the null hypothesis of noninvertibility, since the likelihood ratio is, much taller than the cut-off value, except one case, for confidence level of 95%. I(1) is thus confirmed.

**Table 2: Estimated Univariate Models for the Log of Relative Price Data: ARMA estruture**

| Samp. | Ratio | AR(p) $\phi(B) = (1-\phi_1 B - \phi_2 B^2)$ | | $SF^{(1)(3)}$ $H_0: \phi_1 = 1$ (90%, 95%) | $DCD^{(2)}$ $H_0: \theta = 1$ (90%, 95%) | Mean $\hat{\mu}$ (%) | Innov. St.dev. $\hat{\sigma_a}$ (%) |
|---|---|---|---|---|---|---|---|
| | | $\hat{\phi}_1$ (s.e) | $\hat{\phi}_2$ (s.e) | (1.1, 1.8) | (1.0, 1.9) | | |

**Table 2.A Grains Europe in XVIII Century**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1703-1815 | A/L[3] | .71 (.09) | -.24 (.09) | - | 0 | -.42 (.06) | 34.6 |
| | H/L | .32 (.08) | - | 32.4 | 1.8 | -.23 (.03) | 21.0 |
| | M/L | .67 (.07) | - | 18.0 | .4 | -.24 (.07) | 23.8 |
| | S/L | .61 (.07) | - | 21.5 | 1.0 | -.24 (.07) | 28.3 |
| | G/L | .57 (.08) | - | 24.5 | 4.1 | -.51 (.05) | 25.1 |
| | V/L | .58 (.08) | - | 23.3 | 0 | -.71 (.06) | 26.4 |

**Table 2.B Grains America in XVIII Century**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1720-1815 | PW/L | .40 (.10) | - | 32.2 | 0 | -.47 (.04) | 21.2 |
| | PC/L [3] | .73 (.10) | -.25 (.11) | - | .3 | -1.09 (.04) | 20.4 |
| 1703-1815 | MC/L | .53 (.10) | - | 26.0 | .9 | -.38 (.06) | 32.9 |

**Table 2.C Grains Europe and America in XIX Century**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1867-1896 | H/L | .38 (.16) | - | 8.3 | - | .0022 (.0219) | 7.6 |
| | PW/L | .49 (.16) | - | 5.5 | - | .031 (.020) | 5.6 |
| | PW/U | .23 (.24) | - | 11.7 | - | .030 (.024) | 9.6 |

Notes:
(1) Shin and Fuller (1998) statistic (SF). It test whether an AR(1) operator is non-stationary.
(2) Though estationary seems clear, an additional check is carried out in this case: an ARIMA(2,1,1) is estimated. By DCD we cannot reject the null hypothesis of noninvertibility, except two cases, since the likelihood ratio is, much smaller than the cut-off value, for confidence level of 95%. CI(1,1) is thus confirmed.
(3) Notice that, in the case of an AR(2) with imaginary roots operator, the non-stationary test SF it not justified. In this case, to control for a non-stationary AR(1) we use (2).

**Table 3: Estimated Univariate Models for the Log of Relative Price Data: ARMA estruture (Subsamples)**

| Samp. | Ratio | AR(p) $\phi(B) = (1-\phi_1 B-\phi_2 B^2)$ | | SF $H_0:\phi_1=1$ (90%, 95%) | Barlett $H_0:\sigma^2_{a1}=\sigma^2_{a2}$ (90%, 95%) | Mean $\hat{\mu}$ | Innov. St.dev. $\hat{\sigma_a}$ |
|---|---|---|---|---|---|---|---|
| | | $\phi_1$ (s.e) | $\phi_2$ (s.e) | (1.1, 1.8) | (2.7, 3.8) | (%) | (%) |

**Table 3.A: Grains Europe in XVIII Century**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1703-1792 | A/L(1) | .67 (.10) | -.26 (.10) | - | 5.9 | -.42 (.06) | 32.9 |
| 1703-1757 | | .67 (.13) | -.29 (.09) | - | | -.45 (.08) | 36.6 |
| 1758-1792 | | .62 (.17) | -.36 (.17) | - | | -.35 (.06) | 25.9 |
| 1703-1792 | H/L | .14 (.11) | - | 46.8 | .6 | -.20 (.02) | 19.4 |
| 1703-1757 | | .14 (.14) | - | 27.4 | | -.22 (.03) | 19.9 |
| 1758-1792 | | .11 (.17) | - | 17.7 | | -.17 (.03) | 18.1 |
| 1703-1792 | M/L | .61 (.08) | - | 16.7 | 3.0 | -.18 (.06) | 21.5 |
| 1703-1757 | | .65 (.10) | - | 7.8 | | -.15 (.09) | 23.4 |
| 1758-1792 | | .40 (.16) | - | 9.2 | | -.22 (.05) | 17.5 |
| 1703-1792 | S/L | .56 (.09) | - | 19.6 | 5.9 | -.37 (.06) | 25.7 |
| 1703-1757 | | .59 (.11) | - | 9.4 | | -.35 (.09) | 28.8 |
| 1758-1792 | | .41 (.15) | - | 9.3 | | -.42 (.05) | 19.2 |
| 1703-1792 | G/L | .33 (.10) | - | 33.9 | 1.5 | -.44 (.04) | 20.8 |
| 1703-1757 | | .31 (.13) | - | 20.7 | | -.40 (.04) | 22.0 |
| 1758-1792 | | .28 (.17) | - | 11.5 | | -.49 (.04) | 18.1 |
| 1703-1792 | V/L | .59 (.09) | - | 17.7 | 10.9 | -.71 (.06) | 25.4 |
| 1703-1757 | | .55 (.11) | - | 10.9 | | -.75 (.08) | 28.9 |
| 1758-1792 | | .70 (.14) | - | 1.9 | | -.60 (.10) | 18.3 |

**Table 3.B Grains America in XVIII Century**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1720-1792 | PW/L | .47 (.10) | - | 20.0 | .8 | -.47 (.04) | 18.6 |
| 1720-1757 | | .51 (.14) | - | 7.1 | | -.53 (.06) | 18.9 |
| 1758-1792 | | .35 (.15) | - | 11.2 | | -.41 (.04) | 17.5 |
| 1720-1792 | PC/L(1) | .78 (.11) | -.43 (.11) | - | .6 | -1.05 (.03) | 17.2 |
| 1720-1757 | | .79 (.16) | -.33 (.17) | - | | -1.02 (.05) | 15.9 |
| 1758-1792 | | .62 (.17) | -.35 (.18) | - | | -1.05 (.04) | 18.04 |
| 1703-1792 | MC/L | .57 (.08) | - | 18.2 | .2 | -.33 (.08) | 31.2 |
| 1703-1757 | | .79 (.16) | - | 7.8 | | -.29 (.10) | 30.0 |
| 1758-1792 | | .56 (.14) | - | 5.6 | | -.44 (.12) | 32.2 |

Note: (1) By DCD we cannot reject the null hypothesis of noninvertibility, CI(1,1) is thus confirmed.

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